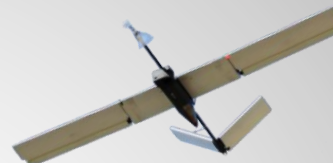
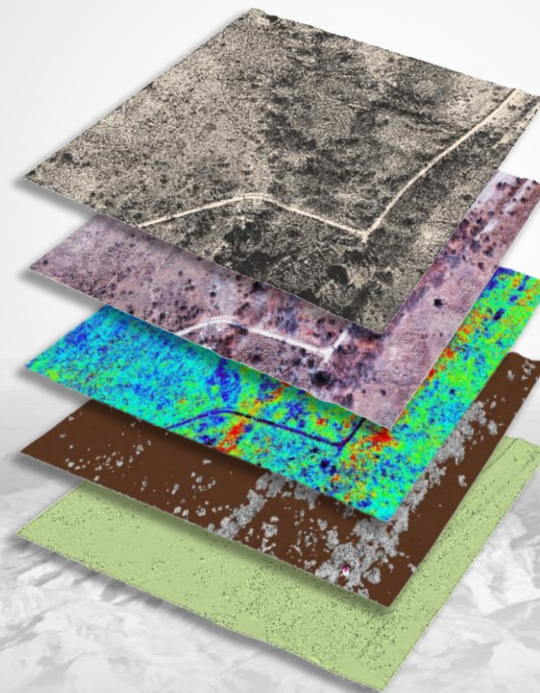


National Unmanned Aircraft Systems (UAS) Project Office



3-D POINT CLOUD DATA
DIGITAL SURFACE MODELS
DIGITAL TERRAIN MODELS
ORTHOIMAGERY
SEGMENTATION AND CLASSIFICATION



Processing UAS Imagery using Agisoft Photoscan

Photogrammetry is the science of making measurements from photographs.

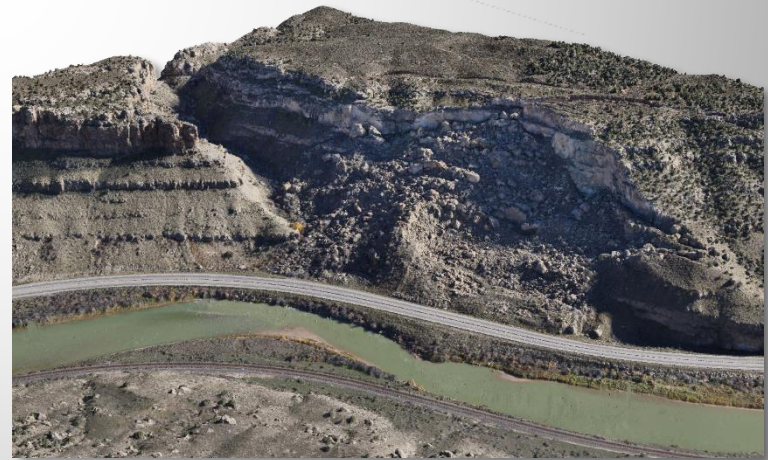
Agisoft Photoscan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images. Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated.

Primary Goal: To model a 3D surface, capturing color reflectance accurately, and minimizing sources of error.

- Photoscan uses computer vision auto matching algorithm to reconstruct a 3D surface. The technique is also sometimes referred to as structure from motion.



Devils Tower, WY
(ground based survey)



Debeque Landslide, CO



Platte River, NE

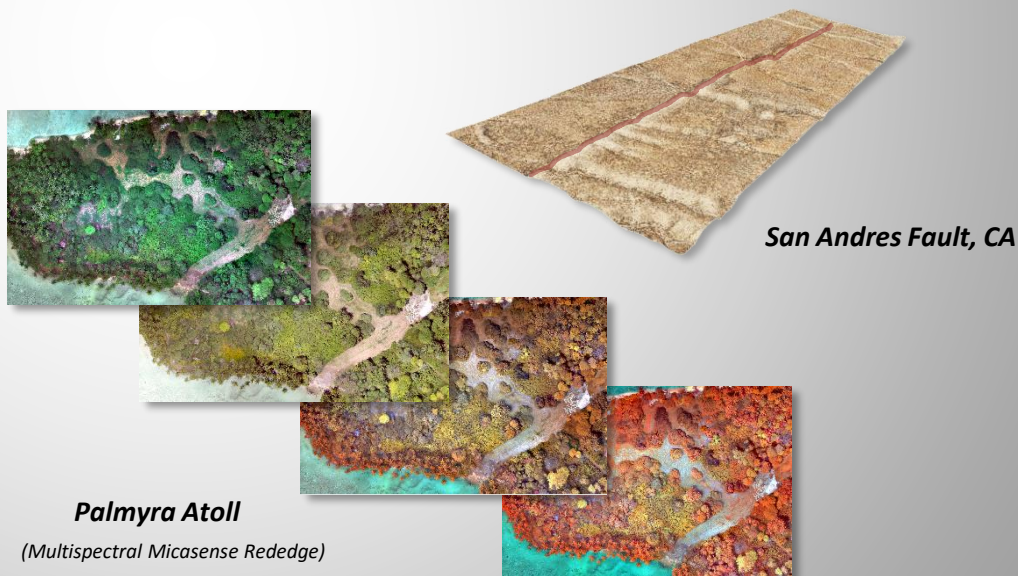
Processing UAS Imagery using Agisoft Photoscan

Example Products produced in Photoscan

Topic Overview

- 1.) Camera Anatomy
- 2.) Photography
- 3.) Geometry
- 4.) Camera Calibration
- 5.) Ground Control / Scale

- Sensors
- Camera Types
- Exposures
- Preprocessing
- Base to Height Ratios
- Camera Orientations
- Lens Distortions
- Camera Calibration
- Ground Control Targets
- Ground Control Distribution



Processing UAS Imagery using Agisoft Photoscan

Photography - What should we target?

- Photoscan has the ability to measure to **0.13** of a pixel. Burry photos will not support those tolerances. Sharp focus, and minimized noise is important!
- Proper exposure, sharp focus, no grain or artifacts, minimize lens movement.
- Use a wide angle lens, change your orientation, proper base to height ratio and overlap.
- High quality surveyed ground control and or IMU systems. Traditionally, 3 times more accurate than you really need.



Sample Image from Chase Lake, ND

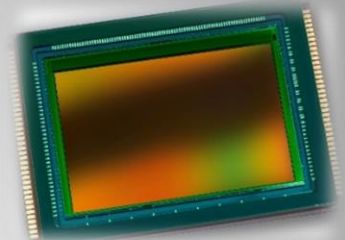


3D reconstruction with camera orientations of Chase Lake, ND

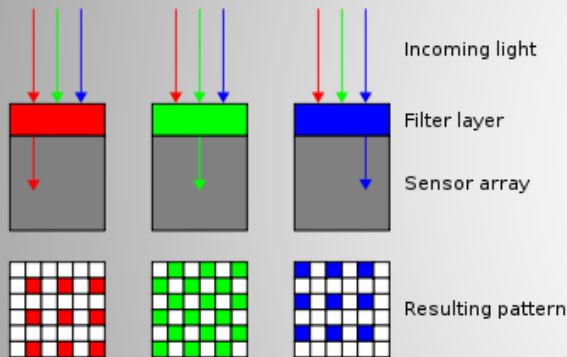
Processing UAS Imagery using Agisoft Photoscan

Imaging Sensors

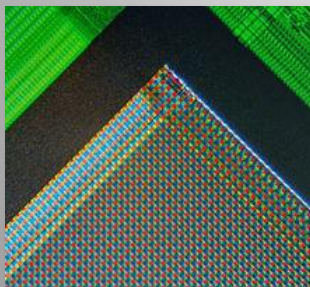
- The **size** of the sensor influences the quality of images.
- Larger sensors have a larger dynamic range. Capturing more color values (Bit Depth)
- Larger sensors have more surface area for lighting and exposure.
- Larger sensors have a larger angle of view. (Crop Factor)
- Larger sensors need a larger lens to cast an image over it.



COTS RGB Cameras



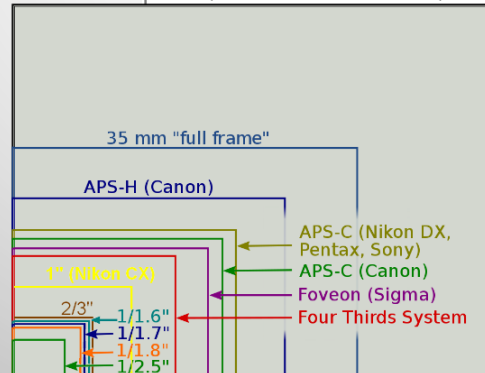
Bayer Filter



Sensor size comparison chart

Type	1/3"	1/2"	2/3"	4/3"	APS-C	Canon Nikon Pentax DX	Super 35	APS-H	35mm Full Frame
sensor w x h	4.8 x 3.6mm	6.4 x 4.8mm	8.8 x 6.6mm	17.8 x 10mm	22.2 x 14.8mm	23.6 x 15.5mm*	24.89 x 18.66mm	28.7 x 19.1mm	36 x 24mm
sensor diagonal	6mm	8mm	11mm	20.41mm	26.7mm	28.4mm	31.1mm	34.5mm	43.3mm
sensor area	17.3mm ²	30.7mm ²	58.1mm ²	178mm ²	329mm ²	366mm ² *	464.44mm ²	548mm ²	864mm ²
crop factor	7.21	5.41	3.93	2	1.62	1.52	1.39	1.26	1

Medium format (Kodak KAF 39000 sensor)



Panasonic AG-AF101	Canon EOS 7D	*Approx	Arri Alexa	Canon EOS 5D MkII
	Canon EOS 60D		Sony PMW-F3	Nikon D3s
	Canon EOS 50D		Sony SRW-9000PL	
	Sony NEX-VG10E		Sony F35	

Processing UAS Imagery using Agisoft Photoscan

Principles of Photography

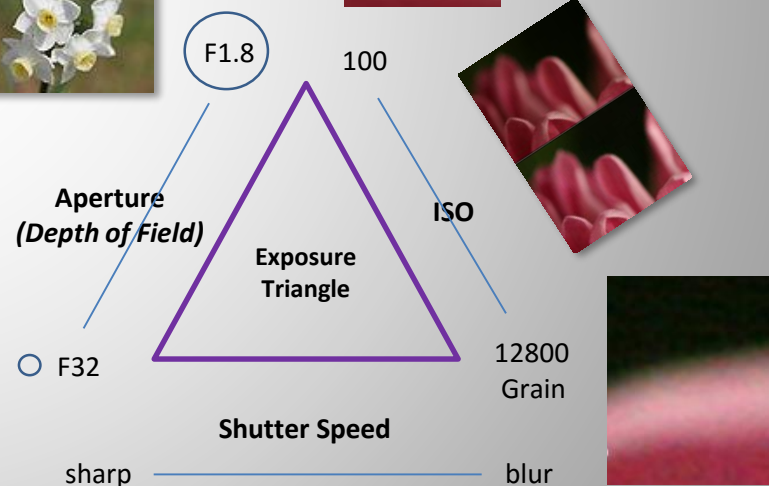
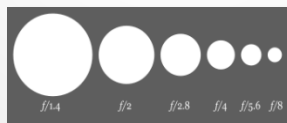
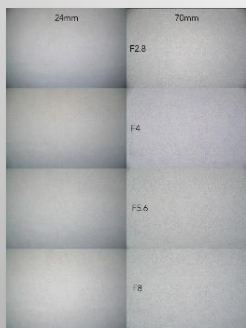
- Pixel sharpness is important when generating tie points. Photoscan has the ability to measure to 0.13 of a pixel.
- Camera anatomy plays an important role in the quality of your photos.



Quality photos are key. Here's a few rules and points to consider.

- 1.) Focal length needs to be fixed.
- 2.) Proper exposure of the image.
- 3.) Proper contrast in the image.
- 4.) Image in focus, but do not change the focus between photos.
- 5.) Depth of Field – Selecting a proper aperture.
- 6.) ISO Selected – Beware of noise.
- 7.) Framed Properly
- 8.) Minimize shadows

Beware of optical vignette effects with changes of your Aperture.



Processing UAS Imagery using Agisoft Photoscan

Photography Topic

1.) High Quality Photos

2.) Good Geometry

Photography / Commercial Off the Shelf (COTS) Cameras

- Having a higher quality camera build is more important than mega pixels.
- Collect in RAW, but typically processing is completed on .JPGs.



Compact Point and Shoot Cameras

- *Typically Smaller Sensors*
- *Lightweight*
- *8 and 12 Bit - Depth*
- *Contrast Based Auto Focus System*

DSLR & MIL Cameras

- *Typically Larger Sensors*
- *Heavier*
- *12 and 14 Bit - Depth*
- *Phase Detection Auto Focus (Mirrorless cameras are a crossbreed)*

Shooting Tips:

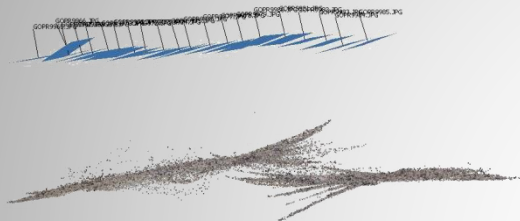
- *Turn off auto rotate*
- *Turn off auto sensor cleaning*
- *Turn off Image Stabilization*
- *Focus to infinity and lock your AF*



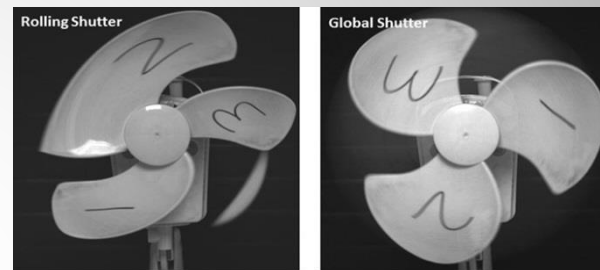
Processing UAS Imagery using Agisoft Photoscan

Rolling Shutters vs Global Shutters

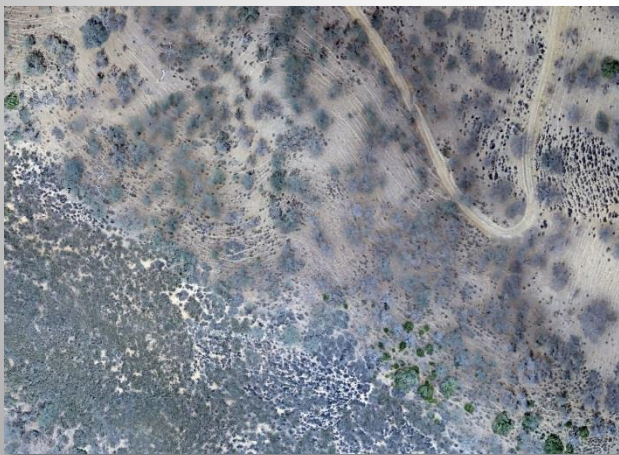
- A rolling shutter exposes the image line by line, usually from top to bottom.
- A global shutter exposes the image across the entire sensor at the same time.



Skew
Wobble
Partial Exposures
Smear



Ortho Image Example



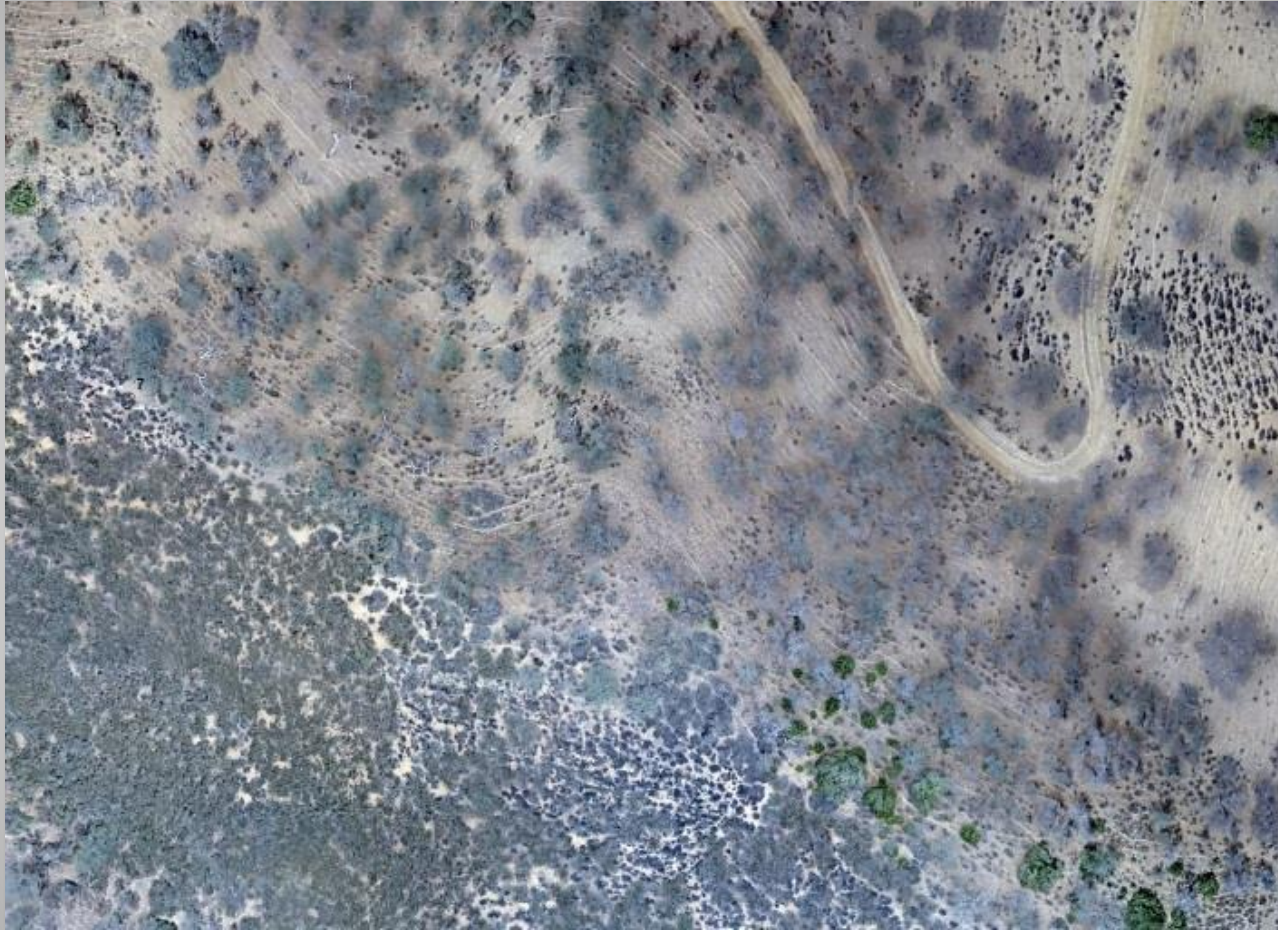
Rolling Shutter – Sony Action Cam



Global Shutter – Ricoh GR

Processing UAS Imagery using Agisoft Photoscan

Rolling Shutters vs Global Shutters



Rolling Shutter – Sony Action Cam

Processing UAS Imagery using Agisoft Photoscan

Rolling Shutters vs Global Shutters

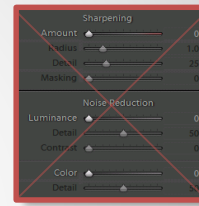
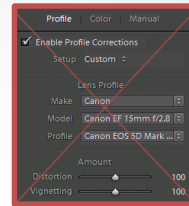
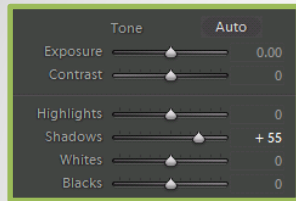


Global Shutter – Ricoh GR

Processing UAS Imagery using Agisoft Photoscan

Pre-Processing (Photoshop / Lightroom / Bridge)

- You **MAY** make exposure changes, highlight and shadow adjustments, and remove chromatic aberration.
- You **CANNOT** sharpen, rotate, use noise filter adjustments, or use lens corrections!



Radiometric Corrections – The goal with these corrections is to obtain the most realistic reflectance values.

- Atmospheric Corrections** - Atmospheric effect caused by absorption and scattering of solar radiation.
- Sensor Sensitivity** - Also known as vignetting, is illumination fall off around the perimeter of the lens.



Illumination fall off



Corrected

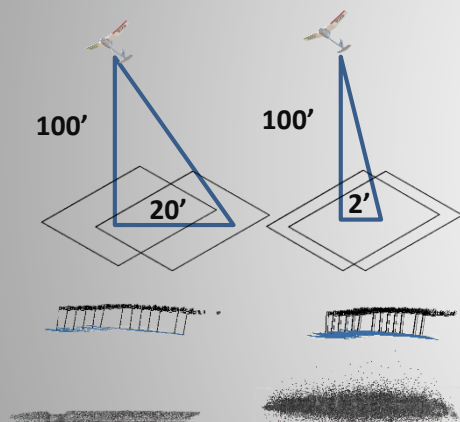
It's important to remember any processing will result in a loss of detail.

Processing UAS Imagery using Agisoft Photoscan

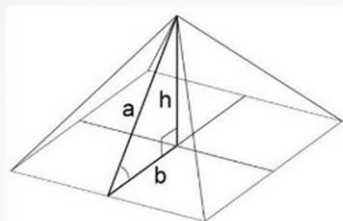
Capturing Your Photos with Good Geometry

- Good photo geometry is very important for the alignment between photos.
- Stereo overlap **66%** side lap **50%**.
- Wide angle lens will improve reconstruction geometry. Stay away from fish eye lens.

Base to Height Ratio



- **1:1** ratio equals about 20% overlap
- **1:2.3** ratio equals about 66% overlap
- **1:5.2** ratio equals about 85% overlap
- **1:7.2** ratio equals about 90% overlap



- Your ability to measure depth (z) goes down when your base to height ratio goes up. This is a direct relationship of photo geometry.
- Base to Height Ratio between **1:2.3** and **1:5.2** is ideal.
- Geometry with Base to Height Ratio of 1:5 has 5 times more potential for error in Z than 1:1

Camera Orientation



Landscape mode – flight direction parallel to long axis of sensor.



Portrait mode – flight direction parallel to short axis of sensor.

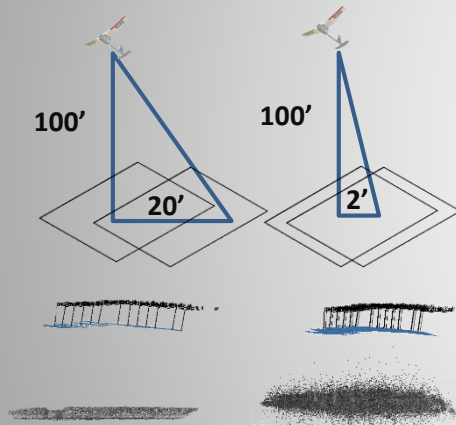
- Multiple Camera orientations will help map the lens distortion by locating the center position (principle point) within your lens calibration model. Rotating your camera at 0°, 90°, 270° is ideal.

Processing UAS Imagery using Agisoft Photoscan

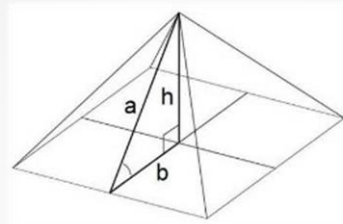
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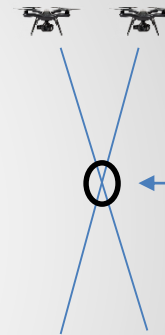
Base to Height Ratio



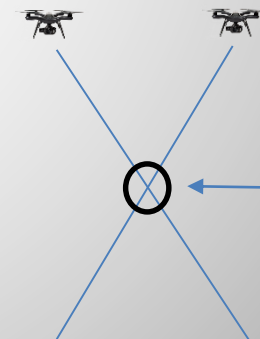
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More uncertainty in your height measurement.



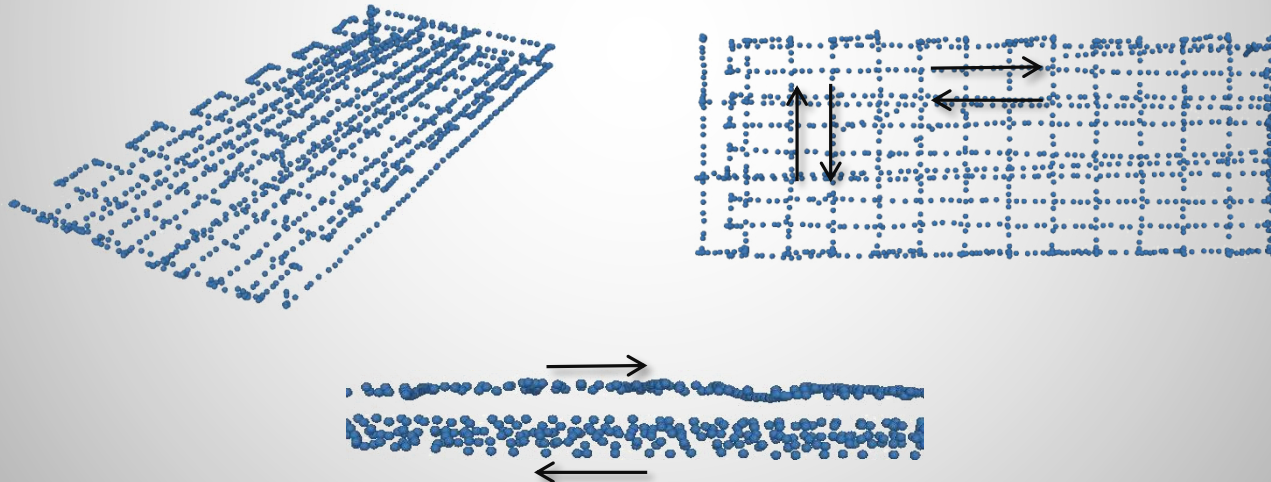
Less uncertainty in your height measurement.

Processing UAS Imagery using Agisoft Photoscan

Capturing Your Photos with Good Geometry

- Good photo geometry is very important for the alignment between photos.
- Changing height is good, but not more than double the scale. The alignment will break.
- Good scale of objects of known length (2 or more) coded targets.

$$\text{GSD} = \frac{\text{pixel size} \times \text{flight height (AGL)}}{\text{focal length}}$$



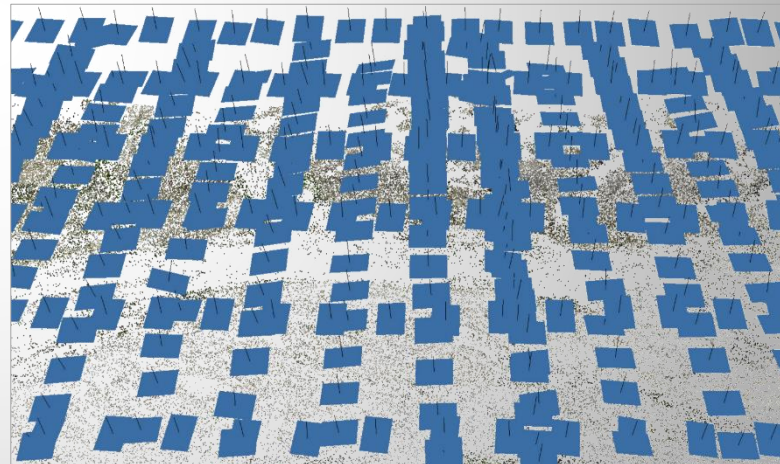
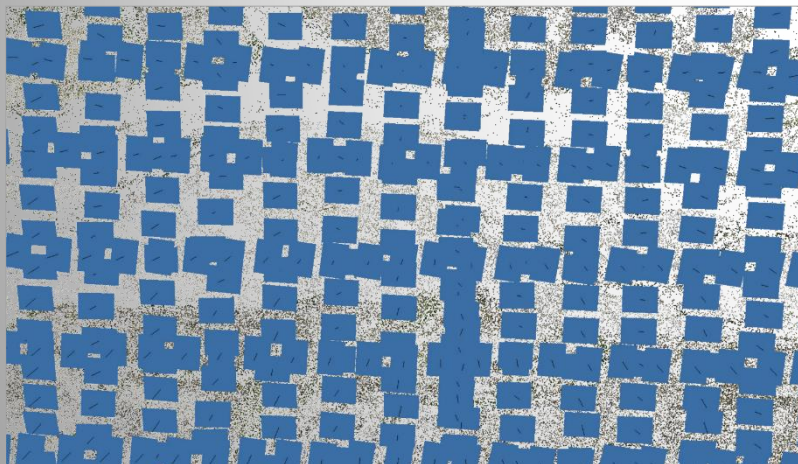
Redundancy is important! (Photos collected between 66% overlap, and 85%) Having more look angles will help construct a better DSM. Also Note: Having redundancy is also important for a height quality camera calibration.

Processing UAS Imagery using Agisoft Photoscan

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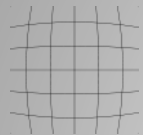


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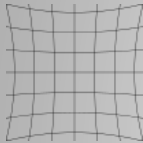
Processing UAS Imagery using Agisoft Photoscan

Camera Calibration and Correcting Lens Distortion

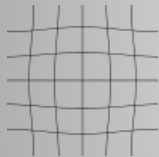
All cameras have some amount of lens distortion. This error needs to be minimized and modeled.



Barrel Distortion

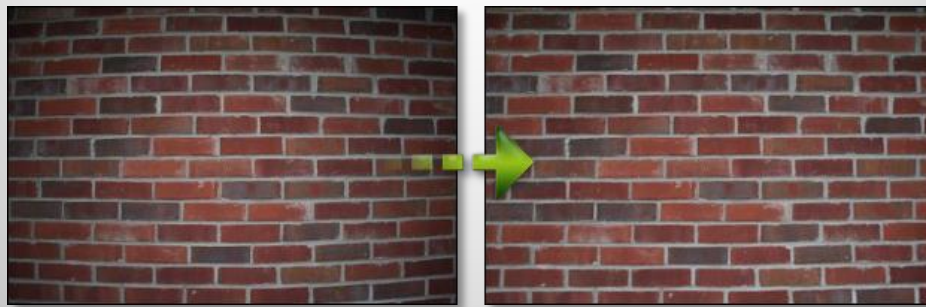


Pincushion Distortion



Complex Distortion

- Photoscan estimates internal and external camera orientation parameters during photo alignment.
- A good camera calibration is critical for surveying with a camera. Variation of photo orientation will help find better measurements during the self calibration process.
- Lens change in size and shape when environmental conditions change. Metric cameras minimize those effect, but those factors still exist.
- **“Optimization” is a least squares bundle adjustment.** The software takes measurements and corrects for radial and tangential distortions.



Processing UAS Imagery using Agisoft Photoscan

Camera Calibration and Correcting Lens Distortion

Coefficients are mathematic expressions of the physical conditions of a lens.

Fc - Focal Length in x, y in pixels

Cx - Principal Point X

Cy - Principal Point Y

K1 - Radial distortion coefficient

K2 - Radial distortion coefficient

K3 - Radial distortion coefficient

K4 - Radial distortion coefficient

P1 - Tangential distortion coefficient

P2 - Tangential distortion coefficient

Skew – Skew transformation

Camera Types (mathematical models) for various lens. Photoscan currently has 3 types.

- 1.) Frame
- 2.) Fisheye
- 3.) Spherical



Processing UAS Imagery using Agisoft Photoscan

Camera Calibration and Correcting Lens Distortion

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Processing UAS Imagery using Agisoft Photoscan

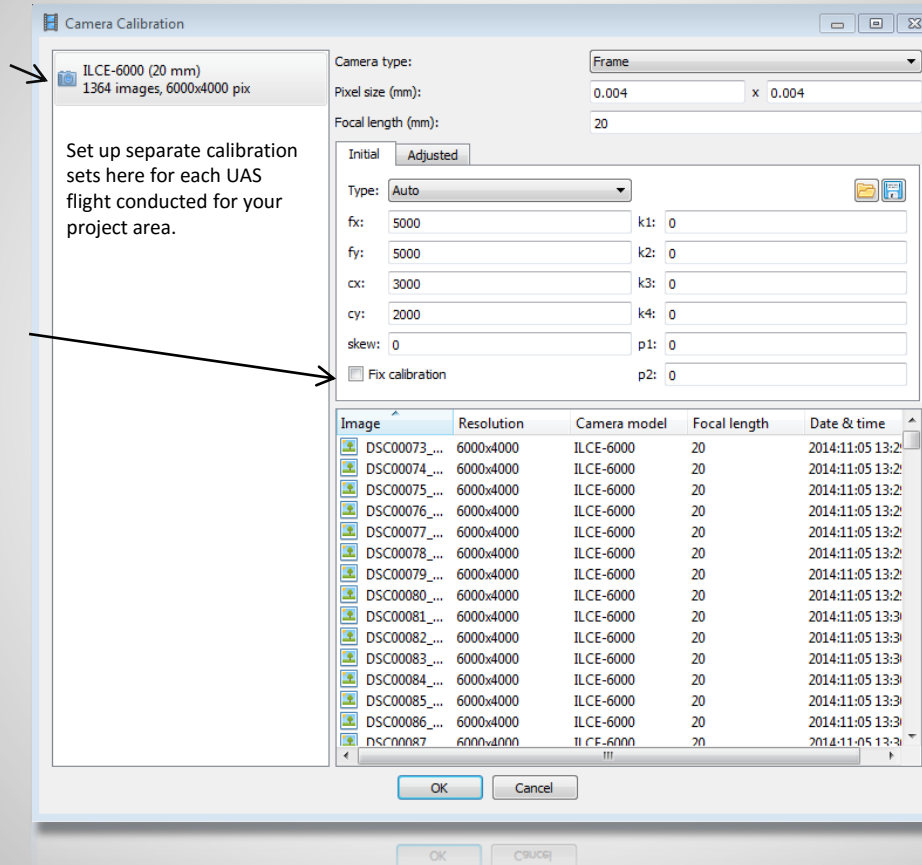
Photoscan Camera Calibration and Lens Distortion Corrections

Multiple Camera Calibration Sets

At this step we want to select our different UAS flights into separate camera calibration groups.

Over Ride Option (Fix Calibration)

Note: The size of the sensor does not get calibrated. The size of your sensor can change (a very small amount) over time.



Camera (Model Type)

Export / Input Camera Model

Image Sets Per Camera Model

Processing UAS Imagery using Agisoft Photoscan

Ground Control, Scale, and Coordinate System

Photoscan can automatically detect pattern targets.

Circular



Cross



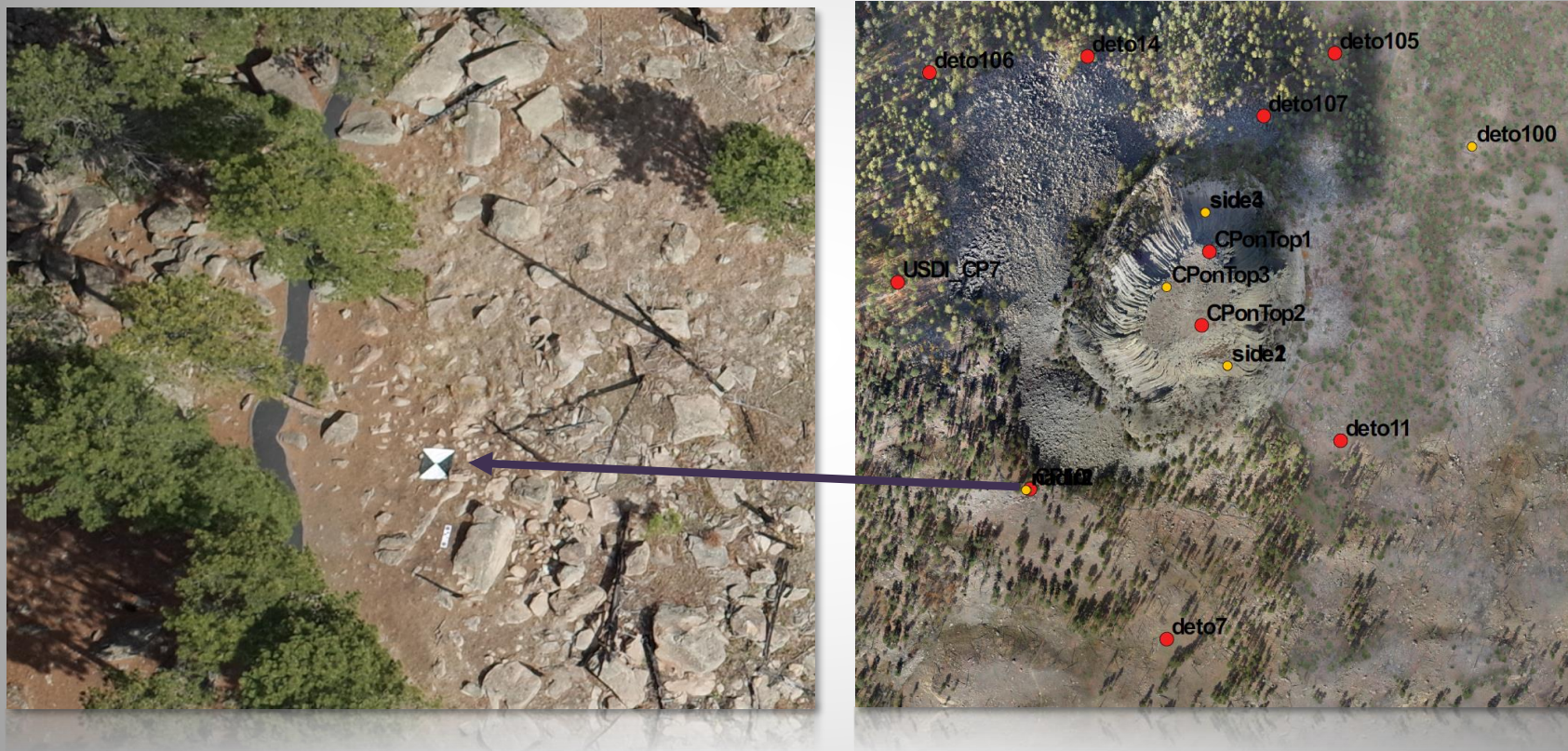
- Tip – Distribute your control points through out the edges of your study site. Pick a few in the center as well.
- Tip – If placing manually, set your GCPs markers on photos that have the target near the center of the photo. Pick the clearest, sharpest photos.



Future UAS system are introducing RTK hardware into the air vehicle platform. The positional data is imbedded into the .exif information.

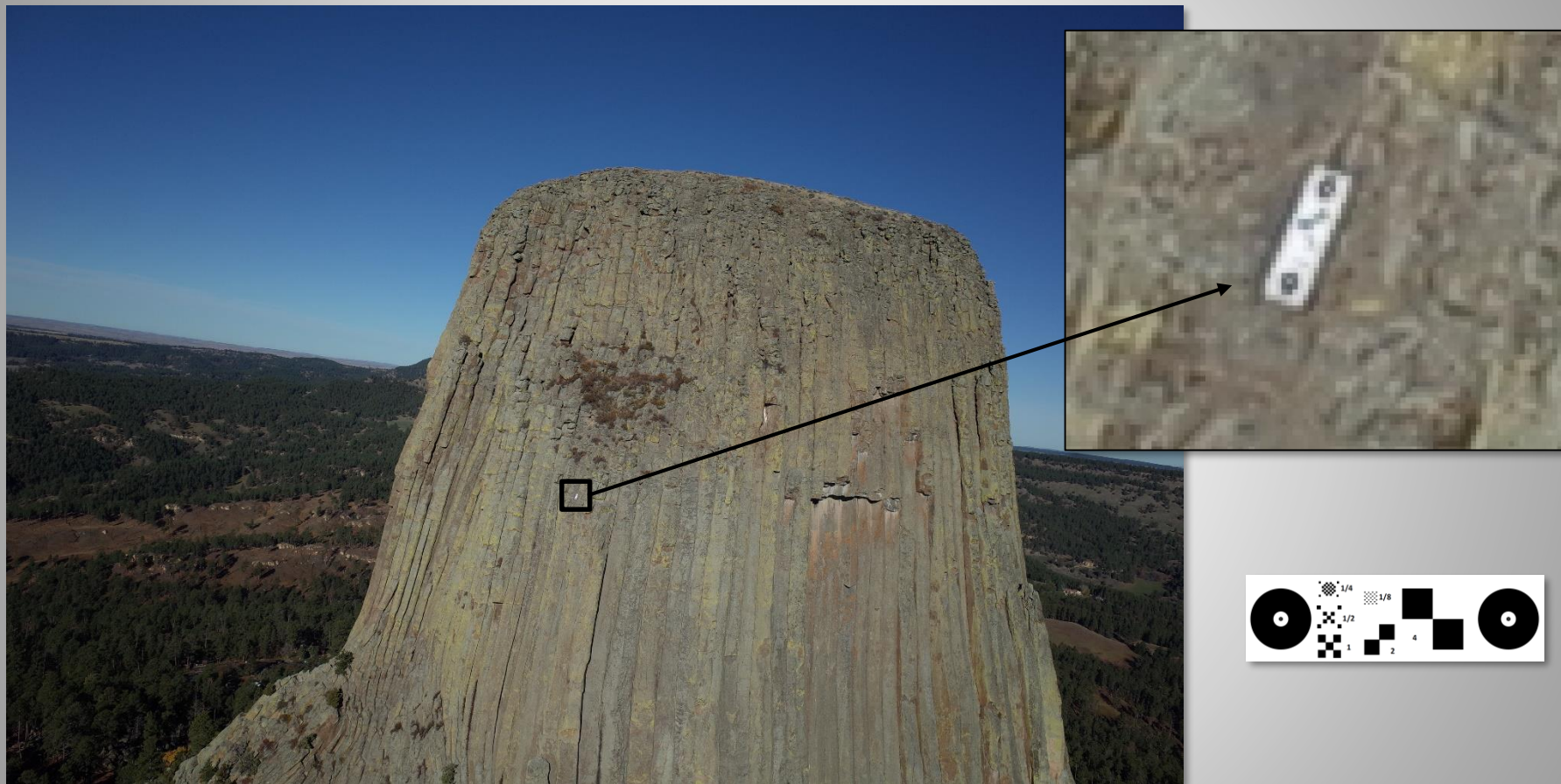
Processing UAS Imagery using Agisoft Photoscan

Ground Control, Scale, and Coordinate System



Processing UAS Imagery using Agisoft Photoscan

Ground Control, Scale, and Coordinate System



Processing UAS Imagery using Agisoft Photoscan

A lot of information!



Source Credits:

**Tom Noble, Neffra Mathews (BLM Photogrammetry Lab)
Mark Bauer, Jeff Sloan, Todd Burton, Joe Adams (USGS UAS Project Office)**

National Unmanned Aircraft Systems (UAS) Project Office



Thank You!
Contact Our Team



Jeff Sloan

Team Lead & Data Analysis
Phone: 303-236-1308
Email: jlsloan@usgs.gov



Mark Bauer

Mission Operator & Data Analysis
Phone: 303-236-1247
Email: mabauer@usgs.gov



Joe Adams

Mission Operator & Data Management
Phone: 303-236-2906
Email: jdadams@usgs.gov



Todd Burton

Mission Operator & Data Analysis
Phone: 303-236-1302
Email: tburton@usgs.gov



Jill Cress

Project & Web Manager
Phone: 303-236-1248
Email: jjcress@usgs.gov



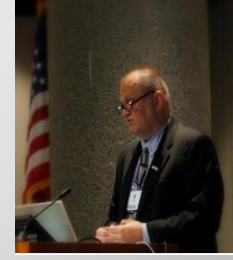
Isaac Anderson

Mission Operator & Data Analysis
Phone: 303-236-5020
Email: ianderson@usgs.gov



Bill Christiansen

National Aviation Manager
USGS
Phone: 303-236-5513
Email: wdchrist@usgs.gov



Bruce Quirk

RPAS Liaison
Phone: 703-648-5736
Email: quirk@usgs.gov